Examiners' Report
June 2017

GCE Physics 9PH0 02

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications come from Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk.

Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

ResultsPlus

Giving you insight to inform next steps

ResultsPlus is Pearson's free online service giving instant and detailed analysis of your students' exam results.

- See students' scores for every exam question.
- Understand how your students' performance compares with class and national averages.
- Identify potential topics, skills and types of question where students may need to develop their learning further.

For more information on ResultsPlus, or to log in, visit www.edexcel.com/resultsplus. Your exams officer will be able to set up your ResultsPlus account in minutes via Edexcel Online.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk.

June 2017

Publications Code 9PH0_02_1706_ER

Introduction

This was the first sitting of this examination for the new specification. The assessment structure of Advanced Paper 2 is the same as that of Paper 1, consisting of ten multiple choice questions and a number of short answer questions followed by longer, structured questions based on contexts of varying familiarity.

The paper introduced two new question styles. Questions 15 and 17(a) assessed the ability to structure answers logically while questions 11, 18(a), 19(b)(iii), 20(b)(i) and 20(b)(iii) all required a judgement with justification of the conclusion. Candidates generally responded well to these, although the conclusions were not always made sufficiently explicit and so the final mark was not always awarded.

The paper allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics by applying them to a range of contexts with differing levels of familiarity. Less able candidates could complete calculations involving simple substitution and limited rearrangement, including structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as converting years to seconds. They also knew some significant points in explanations linked to standard situations, such as polarisation or the photoelectric effect, but missed important details and did not always set out their ideas in a logical sequence, sometimes just quoting as many key points as they could remember without particular reference to the context.

Steady improvement was demonstrated in all of these areas through the range of increasing ability and at the higher end all calculations were completed faultlessly and most points were included in ordered explanations of the situations in the questions.

Questions 1 to 10 – Multiple choice:

Question	Answer	% correct	Most common incorrect choice
1	C	92	D
2	B	68	A
3	B	78	C
4	D	89	B/C
5	B	57	A
6	B	98	-
7	D	79	C
8	D	89	C
9	C	82	A
10	D	47	C

For the following questions, 11 to 20, the mark awarded to each candidate response is shown at the end of the Examiner Comment box.

Question 11

This was a straightforward question to follow the multiple choice section and presented few difficulties to the students. There were several acceptable approaches, most candidates calculating the time or comparing energy transfers.

This was a question requiring a conclusion and some candidates did not make a specific statement, so they were not awarded the final mark. Perhaps because Kelvin is included in the unit of specific heat capacity, some students converted some temperatures from degrees Celsius to Kelvin and got incorrect results. Some used the mass in g rather than kg and some used temperatures rather than temperature differences.

11 An electric iron rated at 2600 W contains a steel plate which is heated to a working temperature of 215 °C. Room temperature is 18 °C.

Deduce whether the plate could reach its working temperature in less than 1 minute.

mass of steel plate = 890 g

specific heat capacity of steel = 450 J kg^{-1} K^{-1}

(3)

$E = mc\Delta\theta$

$E = 0.890 \times 450 \times (215 - 18)$

$= 78{,}898.5$ J

156,000 > 78 898.5 J

$P = \frac{E}{t}$ $\quad Pt = E$

$2600 \times 60 = 156{,}000$ J

So no it couldn't in under 1 minute.

ResultsPlus
Examiner Comments

This candidate has completed the calculations correctly and made a clear comparison between the two energy values, but has drawn the wrong conclusion. **2**

11 An electric iron rated at 2600 W contains a steel plate which is heated to a working temperature of 215 °C. Room temperature is 18 °C.

Deduce whether the plate could reach its working temperature in less than 1 minute.

mass of steel plate = 890 g

specific heat capacity of steel = 450 J kg^{-1} K^{-1}

(3)

$\Delta E = mc\Delta\theta$

$= 890 \times 10^{-3} \times 450 \times (215 - 18)$

$= 78898.5\ J$

$P = \frac{E}{t}$

$t = \frac{E}{P} = \frac{78898.5}{2600}$

$t = 30.3\ s$

ResultsPlus
Examiner Comments

This answer includes fully correct calculations but it does not include a final statement saying that it will reach the required temperature in under a minute because it will only take 30 s. **2**

ResultsPlus
Examiner Tip

When you are asked to make a judgement based on numerical quantities, be sure to make a clear comparison between them, stating the relevant values in your answer.

Question 12

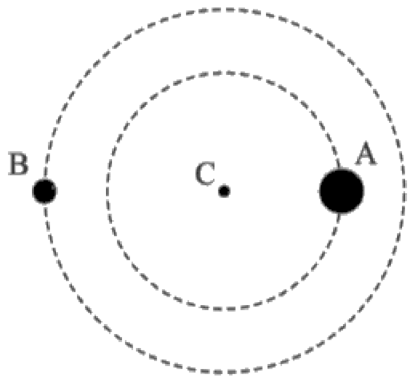
The majority of candidates could apply the correct equations to the calculations in both parts of this question, although errors along the way prevented some from reaching the correct final answer. One problem was that some students did not abstract the required information for each separate part. For part (a) they only needed to think of the force between two masses and for part (b) they only needed to consider the force on a single mass following a circular path, but many conflated these and ended up answering a question about one body orbiting another stationary body, as if one of the black holes was at Point C.

In part (a), candidates occasionally omitted the power of 2 after substituting or in their calculations. Some halved the distance between the black holes, probably linked to the idea of an orbit which was not required for this part of the question. The solar mass was not always written out in the substitution and sometimes the masses used were simply 36 and 29. The unit N was sometimes not given, so the final mark could not be awarded.

In part (b), the final answer required depended on the answer for part (a). Candidates who halved the distance in (a), getting a force four times too large, got an answer to part (b) which was half the value in the mark scheme. A significant number did not simply use the force from part (a), instead deriving an equation linking Newton's law of gravitation to circular motion for an orbit about a central body, which is not the situation in the question. Steps such as the cancellation of *r*, for example, were therefore not valid. Marks were still awarded for use of the formulae in the mark scheme. Some candidates did not seem to find it odd when they obtained answers of a thousandth of a second for an orbit.

12 The diagram shows two black holes, A and B, orbiting each other.

Assume that the centre of mass C of the system is the centre of a circular orbit for each black hole as shown in the diagram.



Black hole A is in an orbit of radius 2.9×10^{10} m and black hole B is in an orbit of radius 3.6×10^{10} m. Both orbit with the same period, so the total distance between them is 6.5×10^{10} m.

(a) Calculate the force between the black holes.

mass of Sun, $M_{\odot} = 1.99 \times 10^{30}$ kg
mass of black hole A = $36M_{\odot}$
mass of black hole B = $29M_{\odot}$

(2)

$F = \frac{Gm_Am_B}{r^2} = \frac{6.67\times10^{-11} \cdot (36M \cdot 29M)}{6.5\times10^{10}} = 4.051 \times 10^{42}$ N

$v = \frac{d}{t}$ $\quad r = \frac{d}{v}$

Force = ...

(b) By considering the orbit of one black hole about C, determine the period of the orbit.

(3)

(B) $F = ma = \frac{mv^2}{r} = \frac{29(1.99\times10^{30})\,v^2}{3.6\times10^{10}} = 4.051\times10^{42}$

$v^2 = \frac{4.051\times10^{42}}{1.6031\times10^{21}}$

$v = \sqrt{\left(\quad\right)} = 5.027\times10^{10}\ \text{m s}^{-1}$

$2\pi r = 2.262\times10^{11}$ m $\qquad \frac{2.262\times10^{11}}{5.027\times10^{10}} = 4.5$ s

Period = 4.5 s

ResultsPlus
Examiner Comments

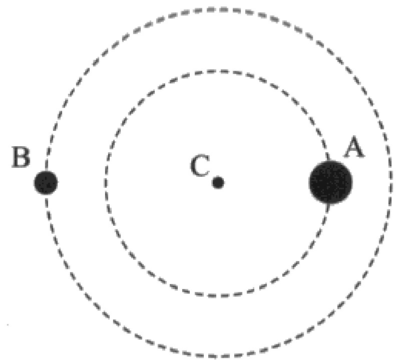
(a) The power of two has been omitted from the substituted formula and from the calculation in this example.
The masses of the black holes have been left as 36M and 29M rather than the numerical values.. Where the mark scheme allows marks for 'use of' a formula, full substitution is required. **0**
(b) The method is fully correct, using the value from part (a), so the answer is accepted using this error carried forward. **3**

ResultsPlus
Examiner Tip

Where a formula includes a squared term, be sure to include the power of 2 when substituting and when carrying out the calculation.

12 The diagram shows two black holes, A and B, orbiting each other.

Assume that the centre of mass C of the system is the centre of a circular orbit for each black hole as shown in the diagram.



Black hole A is in an orbit of radius 2.9×10^{10} m and black hole B is in an orbit of radius 3.6×10^{10} m. Both orbit with the same period, so the total distance between them is 6.5×10^{10} m.

(a) Calculate the force between the black holes.

mass of Sun, $M_\odot = 1.99 \times 10^{30}$ kg
mass of black hole A = $36M_\odot$
mass of black hole B = $29M_\odot$

(2)

$F = \frac{GM_1M_2}{r^2}$

$F = \frac{6.67\times10^{-11} \times 36 \times (1.99\times10^{30}) \times 29 \times (1.99\times10^{30})}{(6.5\times10^{10})^2} = 6.53\times10^{31}$ N

Force = 6.53×10^{31} N

(b) By considering the orbit of one black hole about C, determine the period of the orbit.

(3)

$mr\omega^2 = \frac{Gm_1m_2}{r^2}$

$r\omega^2 = \frac{Gm}{r^2}$

$\omega = \sqrt{\frac{GM}{r^3}}$

$\omega = \sqrt{\frac{6.67\times10^{-11} \times 36 \times 1.99\times10^{30}}{(2.9\times10^{10})^3}}$

$\rightarrow \omega = 1.4\times10^{-5}$ rad s^{-1}

$T = \frac{2\pi}{\omega}$

$T = 4.489\times10^{5}$ s

Period = 4.489×10^{5} s

ResultsPlus
Examiner Comments

(a) This part is correct, with full substitution. **2**
(b) This is an example of a candidate treating this as a situation with a central mass rather than using the force obtained in part (a). The method marks relating to circular motion have been awarded, but the final value is not consistent with the answer in (a). **2**

Question 13 (a)

The great majority knew this definition, although there were some variations, such as ‘an astral body of known luminosity’. Some referred to ‘constant luminosity’ which was not accepted.

(a) State what is meant by a standard candle.

(1)

a star that is stationary so that we can compare it to the stars that are moving.

ResultsPlus
Examiner Comments

This candidate seems to have read the introductory line, about trigonometric parallax, and answered a different question about that rather than the question on the paper. **0**

ResultsPlus
Examiner Tip

If a question seems like one you remember from revision, do not just write that answer. Read the whole question carefully first.

(a) State what is meant by a standard candle.

(1)

A measurement of distance of objects using their luminosity.

ResultsPlus
Examiner Comments

This candidate has made a statement about what standard candles are used for rather than what a standard candle is. **0**

Question 13 (b)

References to the small angle were usually seen, but, if there was any statement about uncertainty, the reference to 'percentage' was rare.

(b) Explain why trigonometric parallax is not used beyond a certain distance.

(2)

Beyond a certain distance the angle that the star seems to shifts compaired to background stars is too small to measure and therefore ~~becau becomes too~~ has a big uncertainty over the size of the angle. This means that parallax can not be used to measure further away stars.

ResultsPlus

Examiner Comments

This answer identifies the small angle and also mentions that it affects uncertainty, but does not refer to relative uncertainty. **1**

(b) Explain why trigonometric parallax is not used beyond a certain distance.

(2)

at larger distances, the parrallax angle gets so small that there is a high percentage error associated with it.

ResultsPlus

Examiner Comments

This is an example of a full mark response, including the two relevant linked points. **2**

Question 13 (c)

There was a problem with reading the whole question here as many candidates wrote out the standard candle description even though the question asked for the method when the distance was too large for standard candles. Those who correctly chose to describe the method based on redshift did not always include all of the required detail, for example referring to a shift but not stating how it was determined based on the difference in wavelength measurements.

(c) Describe how distances too large for the use of standard candles can be determined.

(3)

Using Hubbles constant. measuring recessional velocity of the astronomical object, and Hubbles constant in the equation $V = H_0 d$ rearranged to $\frac{V}{H_0} = d$ to determine distance.

ResultsPlus
Examiner Comments

This response deals with the third part of the answer, using the Hubble constant, well but lacks any detail on how the recessional velocity is determined. **1**

(c) Describe how distances too large for the use of standard candles can be determined.

(3)

- Measure wavelength emitted by the star at earth
- Compare the result with wavelength in laboratory
- Calculate the difference between the two and use doppler formula to calculate speed of star $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$, $v = \frac{\Delta\lambda}{\lambda} c$
- Use Hubble's Law $V = H_0 d$, $d = V/H_0$ to calculate the distance

ResultsPlus
Examiner Comments

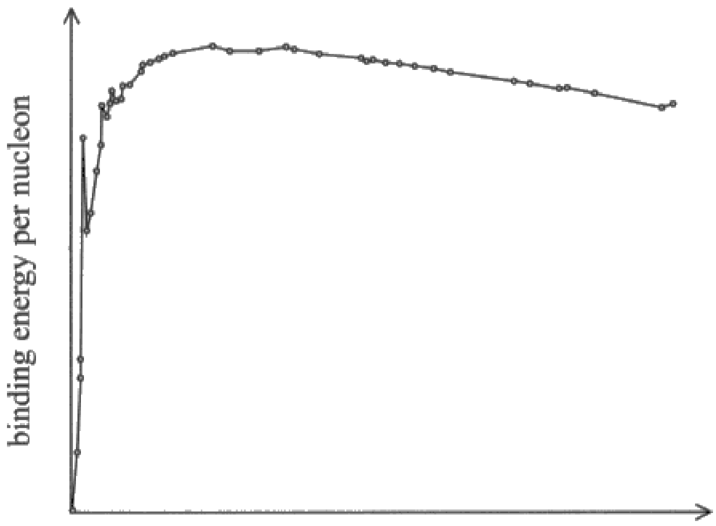
This is a very good, full mark response. The stages are set out in a logical order and linked clearly and velocity and distance are both made the subject of the relevant formulae. **3**

Question 14 (a)

Candidates typically understood the difference between fission and fusion, the initial relative size of the nuclei involved in each process and the part of the graph to which each process applied, but they did not always include the detail required to gain all of the marks. Common missing details were the change in nucleon number in the relevant process, such as fusion resulting in nuclei of higher nucleon number, and the inclusion of 'per nucleon' with binding energy.

14 Nuclear fusion involves small nuclei joining to make larger nuclei. Nuclear fission involves large nuclei splitting to become smaller nuclei. Both of these processes release energy.

(a) The graph shows how the binding energy per nucleon varies with nucleon number for a range of isotopes.



Use the binding energy per nucleon curve to explain how fusion and fission both release energy.

(3)

Since binding energy is ~~equitiv~~ equivalent to mass defect of nucleus, fusion of two light nuclei (lighter than iron) can increase the binding energy per nucleon ~~due to ma~~; so mass of products are smaller, this mass defect will be released ~~as~~ as energy as $\Delta E = \Delta mc^2$.

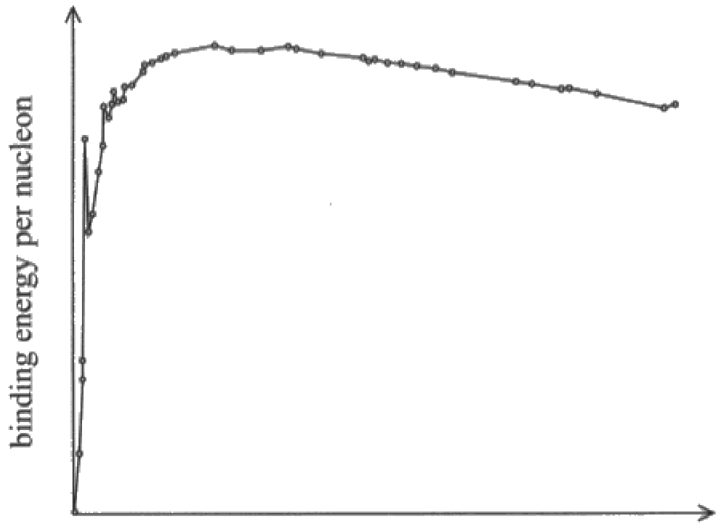
For fission, from the graph, splitting a heavy nucleus (heavier than iron) can increase the binding energy per nucleon ~~of~~ of products, so ~~mass~~ sum of masses of products decreases, which will be released as energy.

Examiner Comments

This response gets credit for linking the increase in binding energy per nucleon to energy released, but does not clearly identify the change in nucleon number for either fusion or fission. **1**

14 Nuclear fusion involves small nuclei joining to make larger nuclei. Nuclear fission involves large nuclei splitting to become smaller nuclei. Both of these processes release energy.

(a) The graph shows how the binding energy per nucleon varies with nucleon number for a range of isotopes.



Use the binding energy per nucleon curve to explain how fusion and fission both release energy.

(3)

For fusion, small nuclei (smaller than Fe) combine to form a larger nuclei with a greater binding energy per nucleon so it has less mass than before which which is relased as energy. For fission, large nuclei (larger than Fe) split to form smaller nuclei w/ a higher binding energy per nucleon, so again energy is relaeeaed
(Fe has the highest binding energy per nucleon so both fission and fusion move towards Fe)

ResultsPlus
Examiner Comments

This is a good example of a full mark answer. The change in nucleon number is linked to the change in binding energy per nucleon for both processes, as is the release of energy. **3**

Question 14 (b)

While high temperature was almost universally mentioned, the partner quantity was often pressure rather than density. This was accepted on this occasion for the first mark only. High temperature was usually stated as necessary to overcome repulsive forces, but the linking step of high energy was not always included. Candidates who only referred to pressure could not be awarded the final mark. The connection between collision rate and maintaining the reaction was infrequently made clear.

(b) Explain the conditions required to bring about and maintain nuclear fusion.

(3)

- Very high temperatures to overcome the electrostatic repelsion between nuclei (as they are positively charged and repel)
- Very high densities to ensure a sufficient collision rate.

ResultsPlus
Examiner Comments

This answer shows a general understanding of the situation, but lacks the required detail to fully answer the question, getting one mark for identifying the conditions but nothing for explaining them. The temperature condition needs an additional reference to high energies of the nuclei and the density condition requires a link to maintaining the reaction. **1**

(b) Explain the conditions required to bring about and maintain nuclear fusion.

(3)

Nuclear fusion requires a high temperature. This gives nuclei enough energy to overcome the repulsive ~~intra molecular~~ ~~internal~~ nuclear forces and successfully fuse. A high density and pressure ensures that the nuclei are close enough to maintain a high frequency of ~~collisions~~ reaction and this keeps the rate of fusion high enough to ~~the~~ continue the process.

(Total for Question 14 = 6 marks)

ResultsPlus

Examiner Comments

This example shows the additional detail required to fully explain the conditions. **3**

Question 15

This was the first of the new linkage questions including marks for structure and lines of reasoning. The majority scored three or more, but almost exactly half scored exactly three. The indicative content most commonly included was the description of the situation at 0° and 90°, although the alignment of the planes of polarisation was not always described correctly. The absorption of perpendicular components or transmission of parallel components was generally satisfactory, fortunately not requiring the actual term 'component'. Candidates often think that all oscillations are only either parallel or perpendicular to the polarising plane of the filter. The idea of components is rare. The term 'polarise' also seems to be used a sort of synonym for 'absorb'.

Explain the effect of the filters on the intensity of light and why the intensity varies as shown.

(6)

~~Emit~~ Light from the bulb is unpolarized. Light that passes through filter 1 is ~~has~~ plane polarized and loses half its intensity due to the polarization. ~~If~~ If filter 2 is ~~pa~~ placed parallel to filter 1 the plane of polarization of both these polarizers align and so the polarized light ~~the~~ from filter passes through filter 2 without being polarized once again and is detected to be ~~ha~~ half of initial intensity. When polarizer 2 is rotated by 90° the ~~the~~ planes of polarization of both ~~polarizeds~~ polarizers are crossed so no light passes through and no light or intensity will be detected. ~~In between 0~~ when the polarizer 2 is 180° to polarizer 1, the planes align again and the intensity is $I_0/2$.

(Total for Question 15 = 6 marks)

In between the ~~alt~~ aligned & crossed planes the intensity ~~is~~ of ~~dec~~ light detected will decrease from $I_0/2$ because only some of the polarized light is able to pass through polarizer 2.

ResultsPlus
Examiner Comments

This response was credited with the inclusion three indicative points, receiving two marks, and one linkage mark, making a total of three marks.
The response notes the initial unpolarised state of the light and the reduction in intensity, but does not say how that is achieved.
The transmission with parallel planes is stated, but the situation for the filter orientation of 90° is described as crossed rather than saying the planes are perpendicular or at 90°.
There is no mention of components in the description of the intermediate stages. **3**

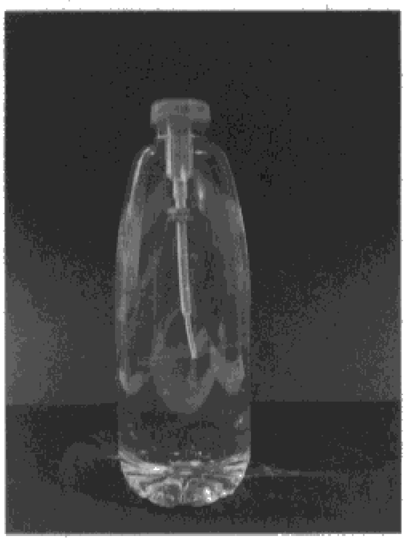
Question 16

About a third of students worked right through the three linked sections successfully. Overall, part (b) yielded the fewest marks.

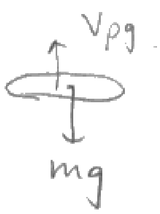
In part (a), some students did not include enough significant figures in their answers for upthrust and weight and then ended up with an answer of 0.02 N, which, not having more significant figures than the 'show that' value quoted in the question, did not gain the final mark. For part (b), candidates were required to show how they arrived at their answer, but some simply applied density = mass/volume to arrive at a correct value but without explanation. Most candidates were able to complete part (c) successfully, although some got the inverse value.

16 A student is investigating a 'Cartesian diver'.

The diver is made from a plastic pipette. When placed in a plastic bottle full of water the diver rises to the top and touches the lid.



(a) Show that the downward force of the lid on the diver is about 0.02 N.



volume of diver = 8.0×10^{-6} m^3

mass of diver = 0.0059 kg

density of water = 1.0×10^3 kg m^{-3}

(3)

$V\rho g - mg = (8\times10^{-6})(1\times10^{3})(9.81) - 0.0059(9.81)$

$= 0.02$ N

By Newton's third law, there will an equal but opposite force acting on the diver by the lid of 0.02 N.

(3)

Vρg = mg ∵ at rest

V(1×10³)(9.81) = 0.0059 × 9.81

V = 5.9 × 10⁻⁶ m³

≈ 6 × 10⁻⁶ m³

(c) The pressure of the air in the empty pipette in part (a) was 1.01×10^5 Pa.

Calculate the pressure of the air in part (b).

(2)

$p_1V_1 = p_2V_2$

$(1.01 \times 10^5)(8 \times 10^{-6}) = P_2(6 \times 10^{-6})$

$P_2 = 1.35 \times 10^5$ Pa

Pressure = 1.35×10^5 Pa

ResultsPlus

Examiner Comments

(a) The process is correct, but the significant figures in the data have not been used in the working. The final answer is given as 0.02 N, the same as the approximate value in the question. The final mark has not been awarded because the answer to a 'show that' question is required to at least one more significant figure than given in the question. Here that is 0.021 N.

Note the small force diagram. Many candidates found such diagrams useful when interpreting the situation.

(b) and (c) are fully correct responses.

(a) **2,** (b) **3,** (c) **2**

ResultsPlus

Examiner Tip

Where a question asks you to 'show that' a quantity has a value given to a certain number of significant figures, you are required to show full working to derive an answer that rounds to the stated value but has at least one more significant figure.

upthrust = ~~the~~ weight of fluid displaced = $9.81 \times 1.0\times10^3 \times 8\times10^{-6}$

density = $\frac{mass}{vol}$ $= 0.07848$

u ~~= F~~ $= 0.0059 \times 9.81 + F$

$F = 0.020601$ N

~~$P = \frac{m}{V}g$~~ $9.81 \times 1.0\times10^3 \times (8 - V) = 9.81 \times (0.0059 +$ ~~$1.0\times10^3 \times V$~~$)$

$V = \frac{mass}{density}$ ~~$8 - V = \frac{0.0059 + 1.0\times10^3 V}{1.0\times10^3}$~~

~~8×10^{-6} $8 - V = \frac{0.059}{1.0\times10^3} + V$~~ ~~$8 - \frac{0.059}{1.0\times10^3} = 2V$~~

$V \times 1.0\times10^3 \times$ ~~9.81~~ $=$ ~~9.81~~ $\times 0.0059$

$V = \frac{0.0059}{1.0\times10^3}$

$= 5.9\times10^{-6}$ m^3

(c) The pressure of the air in the empty pipette in part (a) was 1.01×10^5 Pa.

Calculate the pressure of the air in part (b).

(2)

$P = \frac{F}{V}$ ~~1.01~~ $1.01\times10^5 = \frac{F}{8\times10^{-6}}$

$F = 0.808$

$P = \frac{0.808}{5.9\times10^{-6}} =$ ~~137×10~~ 1.37×10^5

Pressure = 1.37×10^5 Pa

ResultsPlus

Examiner Comments

This is an example of a response fully correct in all parts.
(a) **3,** (b) **3,** (c) **2**

Question 17 (a)

This was the second linkage question with a similar majority scoring three or more. The second observation tended to be explained better than the first observation, perhaps because it was in terms of something that could happen rather than in terms of something that could not. Candidates sometimes just said that normal light did not cause a change because it was below the threshold frequency, without mentioning photons, whereas for ultraviolet they mentioned that photons had energy greater than the work function and caused photoemission.

Sometimes reference was made to $E = hf$, but without saying that this was photon energy. Some simply said that there is a 'one-to-one' relationship between photons and photoelectrons without further detail.

The final two points depended on a time reference, e.g. 'per second', for credit. Some candidates were severely limited because they did not mention photons at all, meaning the maximum available mark was one.

17 A coulombmeter is used to measure charge.

In a laboratory demonstration of the photoelectric effect, a sheet of zinc was placed on top of a coulombmeter and the zinc was given a negative charge.

*(a) The following observations were made:

- under normal lighting conditions the charge remained constant
- when the zinc was illuminated with ultraviolet light, the magnitude of the charge on the zinc decreased as time passed
- when a larger sheet of zinc was used the charge on the zinc decreased more rapidly.

In each case the initial charge on the zinc was the same.

Explain these observations.

(6)

Under normal lighting, electrons will not leave the zinc plate, since E=hf, normal lighting does not provide enough energy for the electrons to escape. When Ultraviolet light is used, electrons start to escape, since the energy provided by each photon exceeds the work function of zinc, Therefore the charge on the zinc decreases. When a larger zinc sheet was used, the surface area of the zinc sheet increased. This allowed more photons to hit the surface every second. Since one photon interacts with one electrons, more photons hitting means more electrons will escape at the same time, Therefore the charge decreased at a faster rate.

ResultsPlus

Examiner Comments

This answer gets four of the indicative content points for three marks and is awarded two marks for linkage, structure and reasoning for a total of five. The answer just states $E = hf$ without saying that this is the energy of a photon. In the reference to normal lighting conditions the required reference to photons is also missing. **5**

Question 17 (b)

The great majority were aware of one of the accepted methods, although some missed out on the plotting method by suggesting plotting ln (charge) against ln (time) rather than just time. Some others quoted the capacitor discharge equation in logarithmic form and said to plot a graph of that equation but did not state the quantities for each axis.

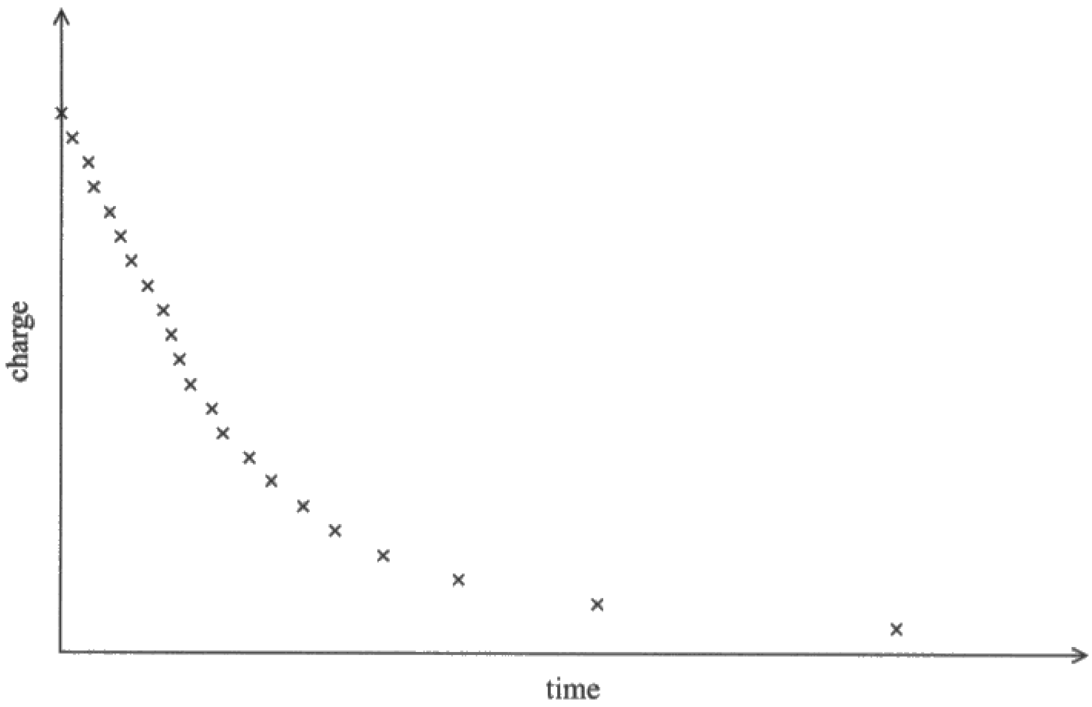
For the plotting method, the straight line was usually mentioned, but not the negative gradient.

The 'half-life' method tended to get both marks more frequently, but sometimes lacked detail about what was being measured. 'Measure the half-life twice and see if it is constant' does not describe what is required.

Candidates did not often support their suggestion by writing the capacitor discharge equation.

(b) For one sheet of zinc, the charge at different times was measured.

The following graph was obtained.



A student suggests that this is an exponential decay curve.
Explain how this suggestion could be tested.

(3)

Measure 2 consecutive half lives by measuring the time elapsed when charge is C and the time elapsed when charge is C/2 and finding the difference in time. Do this twice and if the half lives are the same / very similar then the decrease in charge is exponential decay. (Draw a curve of best fit using the data points)

ResultsPlus

Examiner Comments

This response uses the half life explanation satisfactorily but does not include the exponential equation to justify it. **2**

ResultsPlus

Examiner Tip

Explanations can often be supported by reference to the data, formulae and relationships sheet.

If exponential, should follow equation $Q = Q_0 e^{-kt}$ so $\ln Q = \ln Q_0 - kt$

Thus, plotting a graph of ln charge on y-axis and time on x-axis should yield a straight line with negative gradient if an exponential relationship exists.

ResultsPlus

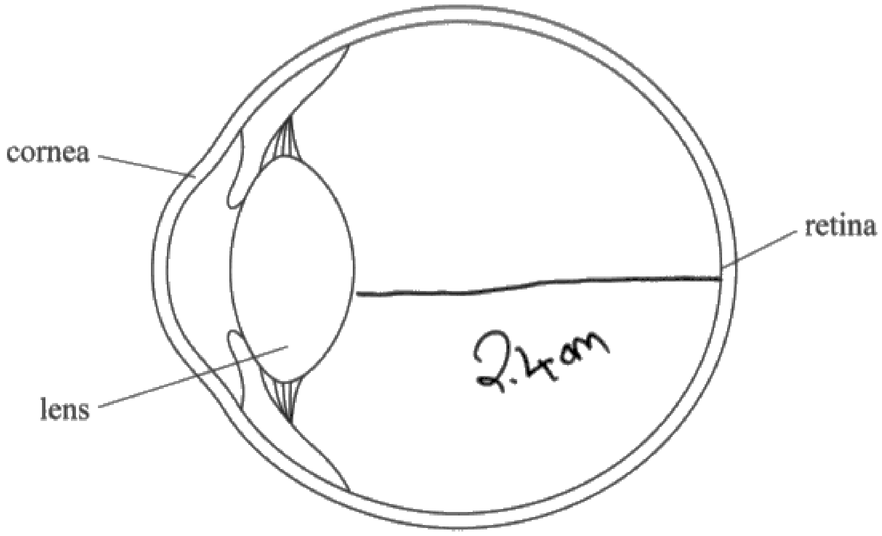
Examiner Comments

This response starts with the equation describing the situation and then describes the required graph and the outcome that determines whether the suggestion is true. **3**

Question 18 (a)

A great majority worked their way through the calculations successfully, including the correct percentage, but slightly under a half of them stated the final conclusion correctly including both percentages with a clear comparison.

18 Light entering a normal eye is refracted by both the cornea and the lens before a focused image is formed on the retina.



(a) It is suggested that the cornea provides 80% of the focusing power of the eye.

Determine whether this is correct.

focal length of cornea = 2.23 cm

focal length of lens for near object = 5.27 cm

(4)

$P = \frac{1}{f}$ Power of cornea $= \frac{1}{(2.23 \times 10^{-2})}$

$= 44.84\,D$

$\frac{18.975}{44.84} \times 100 = 42.3\%$ Power of lens $= \frac{1}{(5.27 \times 10^{-2})}$

$= 18.975\,D$

The lens provides 42.3% of power and so the remaining 57.7% comes from the cornea which is less than 80%

The suggestion is incorrect

ResultsPlus

Examiner Comments

The powers have been calculated correctly in dioptres, but they have not been added. The percentage calculated here is simply that of the cornea relative to the lens rather than relative to the whole system. The conclusion has been given in the correct format, but gets no credit because the quantities calculated are not the correct quantities. Numerical errors would not preclude credit for consistent answers. **1**

$P = 1/f$ and $P_T = P_1 + P_2$

Cornea: $P = 1/2.23\times10^{-2} = 44.8$ Dioptres

lens: $P = 1/5.27\times10^{-2} = 18.97 \approx 19.0$ D

so $P_T = 19 + 44.8 = 63.8$ D

$\Rightarrow$ cornea: $(44.8/63.8)\times100 = 70.2\%$ of Power

so no, cornea provides 70.2% not 80% of power in this case.

ResultsPlus

Examiner Comments

This is a fully correct response including a clear conclusion comparing the relevant quantities. **4**

Question 18 (b) (i)

A similar majority completed this calculation straightforwardly. A few had problems with metres and centimetres, and some added *f* and *u* to get 4.0 cm and used this instead of *u* or *f*. Candidates occasionally failed to find the reciprocal at the end.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{1.6\times10^{-2}\,m} - \frac{1}{2.4cm\times10^{-2}m}$$

$$= 20.8333\ldots m$$

$$= 20.83m$$

Distance = 20.83m

ResultsPlus

Examiner Comments

The substitution has been completed fully and the difference in the reciprocal values has been obtained correctly. The candidate has forgotten that this is not *u* but 1/*u* and has not found the reciprocal of this value. **1**

ResultsPlus

Examiner Tip

Remember the final reciprocal in situations such as those using the lens formula or adding resistors in parallel.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

$f = 0.016\text{m}$ $\quad \frac{1}{f} - \frac{1}{v} = \frac{1}{u}$

$v = 0.024\text{m}$

$u \quad \frac{1}{0.016} - \frac{1}{0.024} = \frac{20.83}{1} = \frac{1}{u} \quad u = \frac{1}{20.83}$

Distance = $\frac{1}{20.83}$ m

ResultsPlus
Examiner Comments

This candidate has arrived at a final value for *u*, but has left it in fraction form, so does not get credit for the final answer. In physics, such fractional answers are not accepted. They must be given in decimal form. **1**

ResultsPlus
Examiner Tip

You must not leave answers to numerical questions in fractional form.

(i) Calculate the distance from the point object to this single lens when a focused image is formed on the retina.

(2)

$\frac{1}{2.4} + \frac{1}{v} = \frac{1}{1.6}$

$\frac{1}{v} = 0.20833..$

$v = 4.8\text{ cm}$

Distance = 4.8 cm

ResultsPlus
Examiner Comments

This answer has been calculated throughout in centimetres rather than metres but, as that is the only quantity involved, the answer arrived at is correct. **2**

ResultsPlus
Examiner Tip

In questions with mixed quantities, be sure to convert all values to standard SI base units or derived units, e.g. convert mm to m, g to kg etc.

Question 18 (b) (ii)

This was also answered well, with full marks going to nearly three quarters of candidates. Those who got no marks had usually used the values for speed of light as values of *n* in the equation.

(ii) A ray of light strikes the front of the cornea at an angle to the normal in air of 15°.

Calculate the angle of the ray to the normal in the cornea.

speed of light in air = $3.00 \times 10^8\ \mathrm{m\,s^{-1}}$

speed of light in cornea = $2.18 \times 10^8\ \mathrm{m\,s^{-1}}$

(3)

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$3.00\times10^8 \times \sin 15 = 2.18\times10^8 \sin\theta_2$

$\dfrac{3.00\times10^8 \times \sin 15}{2.18\times10^8} = \sin\theta_2$

$0.35617 = \sin\theta_2$

$20.9^\circ = \theta_2 \approx 21^\circ$

Angle to normal in cornea = 21°

ResultsPlus

Examiner Comments

This response shows the use of the speed of light in each medium in place of *n*. To use the speeds of light directly they should have been applied the other way round. **0**

$\frac{3 \times 10^8}{2.18 \times 10^8} = \frac{150}{109} = 1.38$

$1.38 = \frac{\theta_1}{\theta_2}$ $\quad 15/1.38 = 10.9°$

Angle to normal in cornea = 10.9°

ResultsPlus

Examiner Comments

A number of candidates arrived at an answer correct to 2 significant figures by this incorrect method. The angles were used instead of their sines. Because the angles are small, the ratio of the angles is almost the same as the ratio of their sines. A mark was still awarded for determination of the refractive index. **1**

Question 18 (c)

Marks were less common here, the most frequent being for a suggestion that the light would focus normally with a layer of air or that there was less refraction with water. After calculating the angle of refraction with water and finding it larger, some incorrectly interpreted this as more refraction rather than less.

Reference to the relative differences in speeds of light was not often seen.

(c) People swimming under water often wear goggles. The goggles enable them to see objects under water clearly whereas without goggles objects appear blurred.

Explain why wearing goggles has this effect.

speed of light in water = $2.25 \times 10^8 \text{ m s}^{-1}$

(3)

~~$A = \frac{3.00 \times 10^8}{2.25 \times 10^8}$~~ $n = \frac{2.25 \times 10^8}{2.18 \times 10^8} = 1.03$

$\theta = \sin^{-1}\left(\frac{\sin(15)}{1.03}\right) \approx 14.5°$ = small change in angle

The speed of light in water is very similar to speed of light in cornea, so ~~both values of~~ values of refractive index of both mediums are very similar, which means that little refraction occurs, so ~~the~~ light doesn't bend as much, and an image can't be focused on the retina so objects appear blurred. With goggles, there is air in front of your eyes so light passing through goggles before your eyes means the boundary on your cornea has a greater difference in refractive index so more refraction occurs and the light bends towards your retina.

(Total for Question 18 = 12 marks)

ResultsPlus
Examiner Comments

This is a fairly good description of the situation, although it is only awarded one of the three marks. While the refractive index has been determined for water to cornea, it has not been compared to the refractive index for air to cornea. The final sentence states that light 'bends' towards your retina without stating that light focuses on the retina. **1**

ResultsPlus
Examiner Tip

Avoid the word 'bend' when describing wave phenomena such as refraction and diffraction.

Question 19 (a)

Most got this correct. Errors seen included using A and Z for a neutron or an alpha particle, reversing A and Z for the beta particle or using A and Z for a positron. Candidates occasionally included a neutrino, but this was not required.

(a) Potassium-40 undergoes β^- decay, producing a stable isotope of calcium.

Complete the nuclear equation for this decay.

(2)

$$^{40}_{19}\mathrm{K} \rightarrow {}^{36}_{17}\mathrm{Ca} + {}^{4}_{2}\beta$$

ResultsPlus

Examiner Comments

This is a rare incorrect response. A and Z for an alpha particle have been applied.

Question 19 (b) (i) – (iii)

Part (i) was successfully completed by most students, although some omitted the percentage quoted earlier.

Part (ii) also caused few difficulties, the most common error being to leave the half-life in years.

In part (iii), many candidates got only a single mark for calculating a corrected count rate, although some did not distinguish between one minute for background and ten minutes for the count. Some determined the corrected count for one minute and calculated this as a percentage of the count for ten minutes, ignoring the value in part (ii). Some compared the count rate of 2.6 per minute with 5 Bq, and there were other variations of mixed times. Many arrived at corresponding values for counts and activity but did not make a clear statement including both values.

(i) The potassium chloride sample has a mass of 300 mg.
Show that the number of nuclei of potassium-40 in the sample is about 3×10^{17}.

number of potassium nuclei in 1 g of potassium chloride = 8.1×10^{21}

(2)

1 g = 8.1×10^{21} $\times 300 \times 10^{-3} \times 0.012\%$

300×10^{-3} g =

$8.1 \times 10^{21} \times 300 \times 10^{-3} \times \frac{0.012}{100}$ = ~~2.916×10^{17}~~

2.92×10^{17}

(ii) Show that the activity of this sample is about 5 Bq.

half-life of potassium-40 = 1.25×10^9 years

(3)

$A = N\lambda$ $\qquad \lambda = \frac{\ln(2)}{t_{1/2}}$

$A = 2.92 \times 10^{17} \times \frac{\ln(2)}{1.25 \times 10^9}$

$A = 1.62 \times 10^8$ Bq ???

(iii) With no sample in front of the Geiger-Müller tube, a count rate of 15 counts per minute is recorded. When the potassium chloride test sample is placed next to the Geiger-Müller tube 176 counts are recorded in a period of 10 minutes.

BGC

17.6 per minute.

A detector is considered efficient if it detects at least 7.5% of beta emissions from the source.

Determine whether this Geiger-Müller tube can be considered efficient.

(3)

17.6 counts per minute.

$17.6 - 15 = 2.6$ Bq

$\frac{2.6}{5} \times 100 = 52\ \%$

→ This giegar Muller tube is efficent as 52 % > 7.5 %.

ResultsPlus
Examiner Comments

(i) This has not been set out brilliantly for a 'show that' question, but it can be followed sufficiently well to award both marks. **2**

(ii) The candidate has used the correct steps in the method, but has been surprised by the incorrect answer. This is because the half-life has been left in years. For a rate in Bq, the half-life must be in seconds. **2**

(iii) There is a similar lack of clarity over time in this part. The corrected count rate has been determined in counts per minute but stated in Bq, i.e. stated in counts per second. The rate has been compared with the 'show that' value from (ii), so credit is given for that. **2**

Question 19 (b) (iv)

In part (iv), although the sample was described as being placed next to the G-M tube, many thought that absorption by air was a major factor in the low proportion of decays detected. They were probably not thinking of decays as such but of beta particles leaving the source in the direction of the detector.

(iv) Explain a possible reason why only a low proportion of the decays are detected.

(2)

~~Because the source is not placed directly on next~~ to the ~~detector or because there~~ the half life of the ~~ca~~ potassium-40 is very large, so there is not much decay happening for it to be detected.

ResultsPlus
Examiner Comments

This response appears to miss the significance of the word 'proportion', referring only to a low count rate and answering a different question. **0**

(iv) Explain a possible reason why only a low proportion of the decays are detected.

(2)

Some of the decay is stopped before it reaches the detector. as Beta decay only has a ~~ro~~ short ranger.

ResultsPlus
Examiner Comments

The question states that the source is next to the G-M tube, but the response suggests that there is a significant separation, answering the question for a different situation. **0**

Question 19 (c)

Candidates did not often realise the significance of the half-life here. While many linked it to the decay rate, this was often in terms of safety factors or uncertainty in measurements. They did not appreciate that the activity could be determined by the quantity used in any case. Some answers were ambiguous, referring to 'it' and not distinguishing between the sources.

(c) The science department also has a sample of strontium-90. This undergoes beta decay with a half-life of 29 years.

State why the half-life of potassium-40 makes the potassium chloride a more suitable material than strontium-90 for the test.

(1)

It has a much longer half life so a ~~lower~~ lower activity. which would be more dangerous if greater

ResultsPlus

Examiner Comments

Here, the reference to 'it' is ambiguous when there are two isotopes in the question. The suggestion is based on safety which is not the relevant point for this question. **1**

The activity of a sample of potassium-40 stays constant for longer whereas as the activity of strontium-90 will decrease quicker so it's harder to know whether the G-M tube is detecting the right amount of beta emissions.

ResultsPlus

Examiner Comments

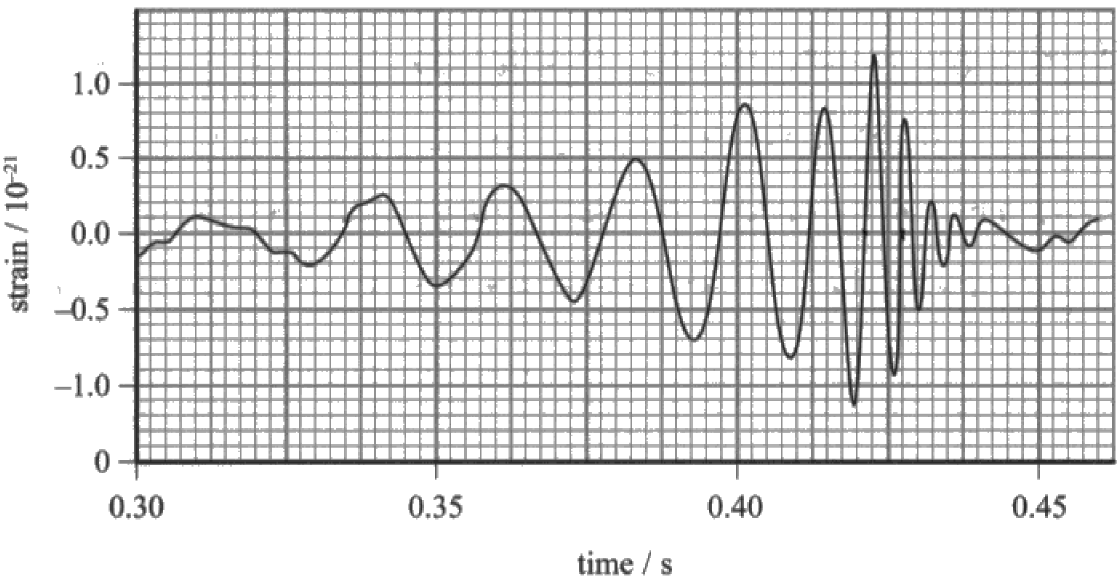
This gets credit for constant activity, clearly referring to potassium. **1**

Question 20 (a)

Most candidates applied the appropriate formulae in the correct way, but not all could determine the period from the graph.

20 In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



(a) Gravitational waves travel at the speed of light.

Determine the mean wavelength of the waves detected between 0.30 s and 0.35 s on the graph.

(3)

$v = f\lambda, \ \lambda = \frac{v}{f} = vT$

$\lambda_{av} = vT_{av}$

$= 3 \times 10^8 \left(\frac{0.35}{2}\right)$

$= 5.25 \times 10^7 \text{ m}$

Mean wavelength = 5.25×10^7 m

ResultsPlus

Examiner Comments

A correct method has been applied but the wrong time has been substituted, possibly by reading 0.35 from the graph and not noticing that the lowest given value is not 0.00. While a calculation based on $s = vt$ would not be accepted, here it is clear that T refers to the period as it follows from $1/f$. **2**

ResultsPlus

Examiner Tip

When using graphs, read the scale values on either side of the point of interest to ensure you are using the scale correctly.

~~$\varepsilon = \frac{\Delta\lambda}{\lambda}$~~

$T = \frac{0.35 - 0.30}{2} = 0.025\,s$

$f = \frac{1}{T} = \frac{1}{0.025} = 40\,Hz$

$c = v = f\lambda$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{40} =$ ~~7500000~~ ~~7500~~ $7.5 \times 10^6\,m$

Mean wavelength = $7.5 \times 10^6\,m$

ResultsPlus

Examiner Comments

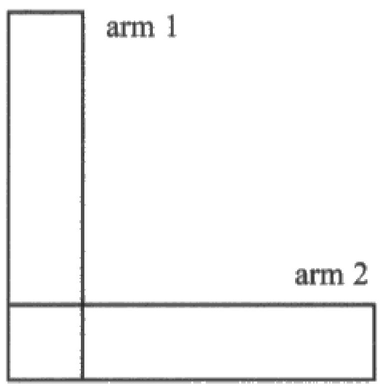
This is a fully correct response. **3**

Question 20 (b) (i)

The majority used the strain equation to arrive at a correct value, either of the maximum change in length or the strain required for a change in length of a thousandth of a proton's diameter. About a third got the full three marks by including the values, with an explicit comparison, in a clear concluding statement.

(b) Gravitational waves alternately compress and stretch matter by very small amounts as they pass through.

The LIGO detector has two arms, at 90° to each other, each 4 km long. As a gravitational wave passes the detector, the arms change length. The detector continuously compares the lengths of the two arms.



(i) An article states that 'the maximum change in the 4 km length of the arm is about 0.001 times the diameter of a proton'.

Determine whether this statement applies to the gravitational wave shown in the graph.

diameter of proton = 8.8×10^{-16} m

(3)

$0.001 \times 8.8 \times 10^{-16} = 8.8 \times 10^{-19}$

$\varepsilon = \frac{\Delta x}{x} \rightarrow \Delta x = \varepsilon x$

$\Delta x = (1.2 \times 10^{-21})(4 \times 10^{3}) = 4.8 \times 10^{-18} = 48 \times 10^{-19}$

∴ No it is not correct.

ResultsPlus

Examiner Comments

This is a fully correct method and includes a concluding statement, but the two values must be included in the statement and a comparison made. **2**

$0.001 \cdot 8.8 \cdot 10^{-16} = 8.8 \cdot 10^{-19}$

$\sigma = \frac{\Delta x}{x} = \frac{8.8 \cdot 10^{-19}}{4 \cdot 10^{3}} = 2.2 \cdot 10^{-22}$

This value for strain is within the range of ~~strange~~ strain seen on the graph so statement applies to the waves shown in the graph.

ResultsPlus

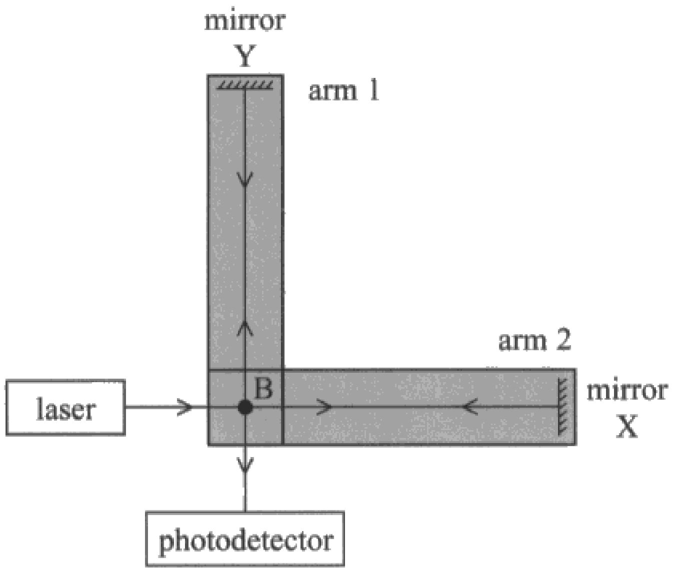
Examiner Comments

This is a fully correct method and includes a concluding statement. The conclusion does not include any values, however. It also refers to the range of strains on the graph whereas the question refers to maximum change. **2**

Question 20 (b) (ii)

Most candidates demonstrated that they had made the connection with interference of light, probably because of the reference to path difference in the question. The level of detail in their application of that concept to this context varied. Of the three standard linked points – path difference, phase difference, amplitude – the majority missed at least one, most commonly phase difference. A good proportion made the final connection between detection and path difference changes.

(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam and photodetector.



The laser beam is split into two at B, one beam travelling to one mirror and the other beam travelling to the other mirror. After reflection at the mirrors, the beams are recombined at B and reach the photodetector. The photodetector measures the intensity of the incident light.

The system is arranged so that when no gravitational waves are present, the beams have a path difference of half a wavelength at the photodetector.

Explain how the photodetector detects very small changes in the length of one arm, when the other arm stays the same length.

(4)

· Light travelling from same source, ~~go~~ so f is the same.
~~λ~~ λ/2 phase difference means when the ~~to~~ reflected light from each mirror meets, they superimpose. · λ/2 phase difference means the maxima of one wave meets the minima of the other, so the overall amplitude = 0, so no intensity at photode

∴ If length changes slightly, then the laser no longer has a phase difference of λ/2 and amplitude increases, giving a reading on the photodetector.

ResultsPlus

Examiner Comments

This response demonstrates a general understanding of the situation, but lacks specific detail and shows imprecise use of technical vocabulary. A mark is awarded for zero amplitude only. Phase difference is referred to in terms of wavelengths, which should be path difference. 'Superimpose' is used instead of 'superpose' and it is not identified as destructive interference, just described as maxima meets minima, which is not correct. The last mark requires a correct reference to a change in path difference or phase difference, but this answer mixes phase and path difference. **1**

ResultsPlus

Examiner Tip

Remember that phase difference is expressed as an angle and path difference is expressed in terms of distance or wavelengths.

$\frac{\lambda}{2}$ path difference means the ~~beal~~ beams are in antiphase and destructively interfere, so I=0. When one of the arms changes its length without the other changing, it changes the path length of one beam, so path difference is no longer $\frac{\lambda}{2}$ and a very small intensity of light is detected. Since the λ of lasers is small, even a tiny ~~movemen~~ change in length can cause a change in intensity that the photodetector can detect.

ResultsPlus

Examiner Comments

This is a full mark response which demonstrates very good application of knowledge and understanding. **4**

Question 20 (b) (iii)

Candidates often found this part difficult to explain, even when their answers hinted at some comprehension. While a good number managed to express the idea that a change from nothing to something would be 'easier' to detect, there were few mentions of relative uncertainty. Some got the situations for half wavelength and zero wavelength path difference mixed up, and very few mentioned maximum intensity.

(iii) The system could be arranged so that when no gravitational waves are present, the beams have zero path difference at the photodetector.

Explain whether using an initial path difference of half a wavelength is a more sensitive way of detecting changes in length than having an initial path difference of zero.

(2)

It is, because there would then be no intensity when they return so any intensity at all ~~differ~~ would reveal a length change. It would be much harder to notice this difference if there were constructive interference where a large intensity would be detected. Small fluctuations in this would be much harder to detect.

ResultsPlus
Examiner Comments

This demonstrates a general understanding but not quite the required level of detail. For example, 'maximum intensity' would have been needed rather than 'large intensity'. **1**

When the initial path difference is zero, the intensity of light will be at it's maximum. Using a path difference of half a wavelength is easier to detect because it's easier to detect a tiny amount of light when you started with zero, but it's harder to detect a tiny decrease in the intensity of light when you start with a maximum.

ResultsPlus

Examiner Comments

While this does not refer to percentage uncertainties, it does have sufficient detail to be awarded both marks, referring to maximum intensity and making a comparison between the two situations. **2**

Paper Summary

Based on their performance on this paper, candidates are offered the following advice:

- For multiple choice questions, only the final answer will be marked. Do use the space available on the paper to work out your answer rather than risk doing it in your head.
- Be sure you know the command words and understand the level of required response for each of them, e.g. explain would mean a candidate must say why something happens and not just describe what happens. There will always be at least two linked marking points for a question asking you to 'explain'.
- Where you are asked to make a judgement or come to a conclusion by command words such as 'determine whether', you must make a clear statement, including any values being compared.
- Check that quantitative answers represent sensible values and to go back over calculations when they do not.
- Learn standard descriptions of physical processes, such as the photoelectric effect and interference, and be able apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question.
- In questions with mixed quantities, be sure to convert all values to standard SI base units or derived units, e.g. convert mm to m, g to kg, kW to W etc.
- Be sure to know the standard SI prefixes and be able to apply the correct power of ten.
- Explanations can often be supported by reference to formulae on the data, formulae and relationships sheet.
- Physical quantities have a magnitude and a unit and both must be given in answers to numerical questions.
- When describing the effects of forces, a simple force diagram can help to understand the situation.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Rewarding Learning

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London WC2R 0RL.